Discussing the Helicopter . . . . .

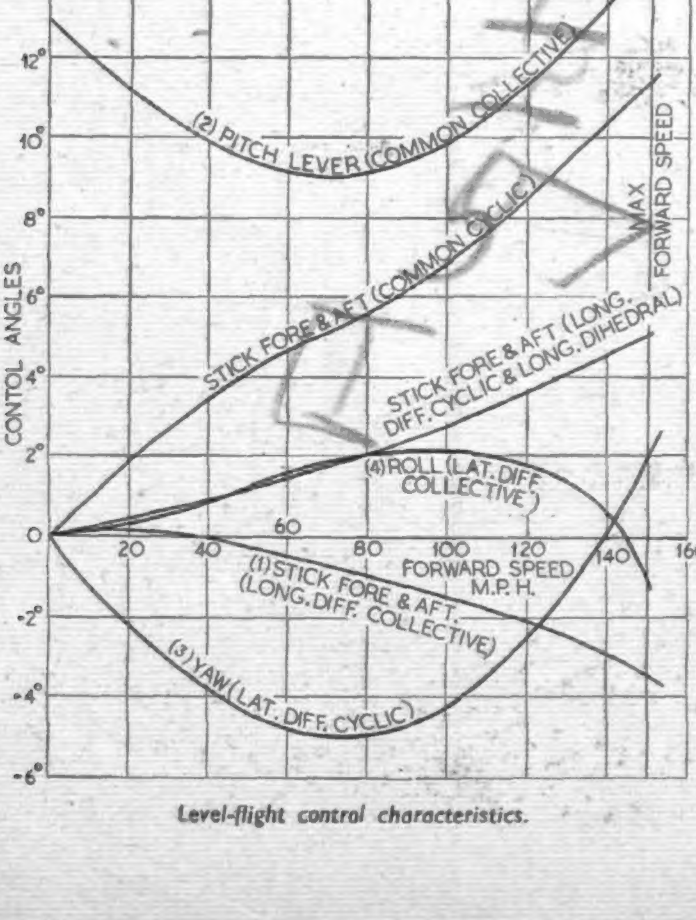
two parallel branches. One branch is a manually released, centrifugally loaded, multi-plate friction clutch with a roller-type freewheel in series. The other branch is an automatic, centrifugal clutch of the roller type, which engages when the rotor system reaches a certain speed of rotation, provided torque is transmitted from the engine. The friction clutch is released by a clutch lever operated by the pilot and engages provided the engine has attained a minimum speed of rotation. Through the friction clutch the rotor system is brought up to speed, and thereupon the roller clutch engages automatically. This latter constitutes its own freewheel. In the event of engine failure, the rotors remain permanently geared together. The clutch unit incorporates the rotor brake manipulated by the clutch release lever.

The distribution gears split the power without speed reduction into three branches of transmission shafting. The shafts run through the outriggers to connect the distribution gear box with the rotor gear boxes and consist of large-diameter aluminium alloy tubes fully protected against deformation of the structure by means of universal joints and flexible couplings. The rotor gear boxes contain two steps of speed reduction, of which the first is a set of straight bevel gears and the second is an epicyclic gear train having straight spur teeth. The gears were supplied by the E.N.V. Engineering Co.

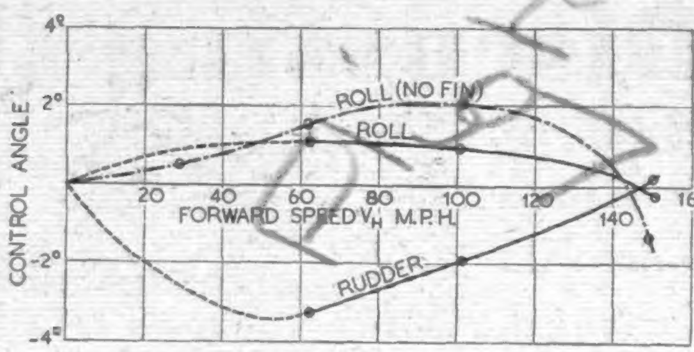
A hub spider is mounted on the epicyclic output shaft. It includes integral flapping pins which carry flapping links on ball and roller bearings. The flapping axes intersect the axis of rotation. The drag link is hinged through needle bearings on the drag pin, situated at five per cent of the blade radius, and carries the torsional articulation, which comprises one double-action, preloaded, large-diameter Timken taper roller bearing. The drag link is restrained in its action by hydraulic dampers.

Rotor blades are manufactured by H. Morris, of Glasgow, and are of all-wood construction but attached with light-alloy fittings, screwed to the spar. The main spar is of high-density, resin-bonded laminated wood. Pressure-moulded skins are checked into the main spar and cover the hollow trailing-edge portion, but are supported by longitudinal auxiliary spars. The blades are of N.A.C.A. 23015 profile. They are tapered in plan form and have appreciable twist.

The flying-control system is interesting, but is difficult to explain without illustrations, which are not available. It is capable of controlling the machine fully, but to improve its



Level-flight control characteristics.



Level-flight control charactistics. Fin controlled by rudder bar. Fin angle 2 x differential cyclic pitch angle.

flying qualities and extend its range of forward speeds it is intended to introduce further control connections, the effects of which were discussed by Mr. Shapiro.

At high speed in forward flight it becomes essential to reduce or suppress the flapping of the blades. This can be done by giving all rotors cyclic pitch control in the same sense and of approximately equal magnitude. The result will be a nearly complete suppression of flapping in level flight, as indicated by one of the diagrams.

Directional control in forward flight is by orientable fins controlled by a trimmer wheel in the cockpit. The control characteristics are shown in a graph. Stability characteristics of a three-rotor helicopter are greatly influenced by the amount of dihedral between the rotor discs. It has been found that negative dihedral contributes to dynamic stability when hovering, while stick-fixed stability in forward flight requires positive dihedral. Provision will be made for producing virtual differential tilt between the front rotor and the two rear rotors. Mr. Shapiro pointed out that the number of possible combinations is very large, and that the selected combination in the Air Horse has been evolved through a long process of elimination.

Control Characteristics

After this description of the Air Horse Mr. Shapiro turned to the subject of control. Control in roll and pitch is extremely powerful, and the control couples "pure" and not associated with horizontal forces until the aircraft has actually changed its attitude. Control in pitch and roll are produced by increments of lift and not by the lift itself, so that basic control functions are operative under all conditions of flight, without exception.

One advantage of the three-rotor layout emphasised by Mr. Shapiro was that it is not nearly so sensitive to c.g. location as is the single-rotor helicopter. In the Air Horse, he said, it can be as far as two feet in front of or behind the mean position, due to the very powerful pitching control.

Next Mr. Shapiro turned his attention to criticisms likely to be advanced, such as complication, weight and drag penalties. The approach was through the point of view of the operator selling helicopter communication, and the overriding aim "to provide helicopter transport services at low cost in terms of pence per ton-mile or passenger-mile at a speed leaving a substantial margin compared with ground transport, accompanied by the highest possible safety."

Once commercial operation was considered, Mr. Shapiro said, the criticism of complication lost its significance as an independent yardstick. It must be expressible in terms of first cost and maintenance. He believed that multiplication of components would tend to cheapen manufacture. Final judgment of maintenance would have to await practical experience. The good accessibility in the Air Horse would help to outweigh the disadvantages of multiplication.

There then remained to examine the three-rotor configuration from the point of view of performance in terms of transport economics. The evaluation was divided into two main considerations: the three-rotor configuration and the long-travel undercarriage.

The first question was: were the advantages of the three-rotor helicopter accompanied by weight and drag penalties leading to increased cost of helicopter transport? From the safety point of view, there could be no doubt that the powerful control, the stability, and the wide undercarriage base with high energy absorption, combined to make the three-rotor the safest type under development. The next step to improved safety lay in twin-engined power plants, and the Cierva firm had in the design stage such a type, to be powered by two